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Research Document 2010/058 | **Document de recherche 2010/058**

Spatial Analysis of Coral and Sponge Densities with Associated Fishing Effort in Proximity to Hatton Basin (NAFO Divisions 2G-0B)

Analyse spatiale des concentrations de corail et d'éponge avec l'effort de pêche associé à proximité du bassin Hatton (divisions 2G-0B de l'OPANO)

V.E. Wareham, L.M.N. Ollerhead and K. Gilkinson

Northwest Atlantic Fisheries Centre
Department of Fisheries and Oceans
Science Branch, St. John's, NL, A1C 5X1

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)
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Correct citation for this publication:

Wareham, V.E, Ollerhead, L.M.N. and Gilkinson K. 2010. Spatial Analysis of Coral and Sponge Densities with associated Fishing Effort in Proximity to Hatton Basin (NAFO Divisions 2G-0B). DFO Can. Sci. Advis. Sec. Res. Doc. 2010/058. vi + 34 p.

ABSTRACT

A national Canadian Science Advisory Secretariat (CSAS) science advisory process was called (March 9-12, 2010) to aid in advancing Canada's domestic and international commitments to manage impacts of fishing on sensitive benthic areas. A fundamental piece of information which is necessary to begin addressing questions of conservation of corals and sponges is their distribution in Canadian waters and the distribution and extent of 'significant' concentrations (= areas) of corals and sponges. The following Newfoundland and Labrador Region contribution focuses on an area in Hatton Basin in the Northwest Atlantic. The rational for selecting this study area was due to the location of important coral and sponge concentrations identified in earlier studies. In addition, the area is recognized as an area of high coral and sponge by-catch by the fishing industry which led to a voluntary industry closure to fishing in 2007.

Data on coral and sponge biomass and species richness were collected from by-catch records taken during the Northern Shrimp Stock Assessment Survey (2005-2008) and Groundfish Stock Assessment Surveys (1996-1999). The Northern Shrimp Stock Assessment Survey was used to model densities of corals and sponges, species richness, and to provide information on location of unsuccessful sets as a result of trawl net tear-ups which may be interpreted as an index of rough, hard ocean floor terrain, and therefore, possible prime coral habitat. Coral species were grouped into conservation units (bins) based on similar morphologies and life histories (growth rates and longevity).

A GIS-based density analysis was used to calculate and map the spatial distribution of areas of significant coral and sponge catches in NAFO divisions 2G-0B from the various surveys that took place between 2005 and 2008 and recorded data from 974 fishing sets. Data was modeled using the methodology from Kenchington et.al. (2009). Using these methods, density analysis was used to calculate and map the significant areas of corals and sponges based on biomass and areas of species richness. Commercial fisheries log book data was used as a coarse index of fishing effort through a specific time period (1998-2009) by fishery, and gear types based on recorded locations of fishing activities. The spatial distribution of fishing effort was coarsely compared with the distribution of significant areas of corals and sponges. The location and trends in distribution of significant areas of conservation units, i.e. coral and sponge groupings are discussed.

RÉSUMÉ

Un processus national d'avis scientifique du Secrétariat canadien de consultation scientifique (SCCS) a eu lieu (du 9 au 12 mars 2010) afin d'aider à avancer les engagements nationaux et internationaux du Canada pour gérer les effets de la pêche sur les zones benthiques vulnérables. Un élément d'information fondamental qui est nécessaire pour commencer à régler les questions de conservation des coraux et des éponges est leur distribution dans les eaux canadiennes, ainsi que la distribution et l'étendue des concentrations « importantes » (= aires) de coraux et d'éponges. Le document ci-dessous, produit par la région de Terre-Neuve et du Labrador, porte sur une zone du bassin Hatton, dans l'Atlantique Nord-Ouest. La justification du choix de cette zone d'étude est qu'il s'y trouve d'importantes concentrations de corail et d'éponge, selon ce qui a été établi lors d'études précédentes. En outre, il est reconnu que l'industrie de la pêche y a un taux élevé de prises accessoires de corail et d'éponge, ce qui a mené, en 2007, à une fermeture volontaire de la pêche par l'industrie.

Les données sur la richesse d'espèces et la biomasse de corail et d'éponge ont été recueillies à partir des rapports de prises accessoires produits lors du relevé d'évaluation des stocks de crevettes nordiques (2005-2008) et des relevés d'évaluation des stocks de poissons de fond (1996-1999). Le relevé d'évaluation des stocks de crevettes nordiques a servi à modéliser les concentrations de coraux et d'éponges, la richesse des espèces, ainsi que pour donner de l'information sur l'emplacement des traits infructueux obtenus par suite de la déchirure du chalut, ce qui peut être interprété comme un indice de fond océanique à la surface rugueuse et dure et, par conséquent, un habitat qui serait parfait pour le corail. Les espèces de coraux ont été groupées par unités de conservation (casiers) en fonction des similarités morphologiques et de l'historique de vie (taux de croissance et longévité).

On a utilisé une analyse de concentration reposant sur le SIG pour calculer et cartographier la distribution spatiale des zones de prises importantes de corail et d'éponge dans les divisions 2G-0B de l'OPANO, à partir des divers relevés qui ont été faits entre 2005 et 2008 et des données qui ont été enregistrées pour 974 ensembles de pêche. Les données ont été modélisées en utilisant la méthodologie de Kenchington et.coll. (2009). À l'aide de ces méthodes, on a utilisé l'analyse de concentration en vue de calculer et de cartographier les zones importantes de coraux et d'éponges en fonction de la biomasse, ainsi que les zones de richesse d'espèces. Les données des journaux de bord de pêche commerciale ont été utilisées comme indice approximatif de l'effort de pêche pendant une période précise (1998-2009), selon le type de pêche et d'engin pour les emplacements consignés d'activités de pêche. La distribution spatiale de l'effort de pêche a été sommairement comparée avec la distribution des zones importantes de coraux et d'éponges. Il est question de l'emplacement et des tendances pour la distribution des zones importantes d'unités de conservation, c.-à-d., les groupements de corail et d'éponge.

INTRODUCTION

BACKGROUND

The UN General Assembly Resolution 61/105 and the supporting Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2009), identified cold water coral and sponge fields as vulnerable marine ecosystems (VMEs) and called upon member states and regional fisheries management authorities to identify VMEs in their jurisdictions and to adopt measures for their protection from serious adverse impacts from fishing operations. To this extent, the NAFO working group, "Working Group on the Ecosystem Approach to Fisheries Management" (WGEAFM) has been examining methods to map significant concentrations of corals and sponges based on trawl by-catch records in the NAFO Regulatory Area (NAFO 2008a,b; Kenchington et al. 2009). In support of international commitments, Canada is domestically implementing the Sustainable Fisheries Framework (SFF) with the underlying principle of incorporating precautionary and ecosystem approaches into fisheries management which includes managing impacts on biodiversity and fisheries habitat. Canada is moving ahead in this area through the development of a number of regional coral and sponge conservation strategies which outline conservation, management, and research objectives that reflect fishing and non-fishing impacts on corals and sponges in Canadian waters. In addition, the National Centre of Expertise for Cold Water Corals and Sponge Reefs has requested science advice to address questions related to: (i) what constitutes significant aggregations of corals and sponges?, and, (ii) what is the distribution and composition of these aggregations? In response to these questions and objectives, a national Canadian Science Advisory Secretariat (CSAS) science advisory process was scheduled (March 9-12, 2010) to aid in advancing Canada's domestic and international commitments to manage impacts of fishing on sensitive benthic areas. Regional working papers, including the current research document, were considered the primary information sources for consideration at this science advisory process. A fundamental piece of information which is necessary to begin addressing questions of conservation of corals and sponges is their distribution in Canadian waters and the distribution and extent of high concentrations of corals and sponges. The Newfoundland and Labrador region's contribution focused on an area in Hatton Basin known to be a coral 'hotspot', and which is in the vicinity of a voluntary industry closure.

With respect to the workshop objectives, this Research Document addresses the following questions:

1. Following the modeling methods of the WGEAFAM, what are the spatial patterns of distribution of coral and sponge densities (biomass mapping)? What is the distribution and areal extent of high concentrations? At what catch thresholds do we see the greatest percent change in area of coverage?

2. Does coral species richness show any relationship to patterns of coral biomass? (Note: given the current state of taxonomic knowledge for sponges, a similar analysis for this group is not yet possible.)

3. What are the spatial patterns of commercial fishing activity, and in particular, what is the degree of overlap of fishing activity with identified high coral and sponge concentrations?

Scope

The geographic coverage will focus on Hatton Basin and surrounding areas encompassing NAFO divisions 2G and 0B in the Labrador Sea (Fig. 1). This area contains several physiographic features, such as, the Southeastern Baffin Shelf, Hatton Basin, and the northern portion of the Labrador Shelf including Saglek and Okak Banks.

The rational for selecting this study area was due to the location of important coral and sponge concentrations identified in earlier studies (MacIsaac et al., 2001; Gass and Willison, 2005; Wareham and Edinger 2007; Gilkinson and Edinger, 2009; Wareham 2010). In addition, the area is recognized as an area of high coral and sponge by-catch by the fishing industry (MPA News, 2007).

Kenchington et al. (2010) provide an analysis of coral and sponge densities for the entire East Coast of Canada by Biogeographic Zones as set out by the Biogeographic Classification Framework Workshop (see DFO 2009).

However, the present paper will use NAFO divisions to delineate study area boundaries which straddle two biogeographic zones: NL-Labrador Shelf Biogeographic Zone and Eastern Arctic Biogeographic Zone. The justification for selecting NAFO divisions over Biogeographic Zones was in order to focus on Hatton Basin and the surrounding areas. As well, the boundary line between NL-Labrador Shelf Biogeographic Zone and Eastern Arctic Biogeographic Zones is unclear and data-poor based on the Biogeographic Classification Framework (DFO 2009).

It is important to note that in May 2007 a *Voluntary Coral Protection Zone* was initiated and implemented by three fishing industry organizations: Groundfish Enterprise Allocation Council (GEAC), Canadian Association of Prawn Producers (CAPP), and the Northern Coalition (NC). The *Voluntary Coral Protection Zone* has an area of ~12,500 km^2 and is located immediately adjacent to the Hudson Strait in Hatton Basin and falls on the boundary line between NAFO divisions 2G and 0B (MPA News 2007). The purpose of the closure is to avoid fishing-related damage to specific species of gorgonian corals and one order of antipatharian corals which includes; *Primnoa resedaeformis* Gunnerus 1763, *Paragorgia arborea* Linnaeus 1758, *Paramuricea placomus* Linnaeus 1758, *P. grandis* Verrill 1883, *Keratoisis ornata* Verrill 1878, and antipatharian black corals (MPA News 2007).

METHODOLOGY

PROCESS

Methodologies for determining significant concentrations of corals and sponges were developed by NAFO and meet the FAO guidelines for vulnerable marine ecosystem components (FAO 2009). Spatial analysis modeling was later developed by Kenchington et al., (2009) to advance original methodologies. Analyses presented here followed the latter approach to help identify spatial patterns of coral and sponge concentrations within Hatton Basin and surrounding areas.

DATA SOURCES AND LIMITATIONS

Data used was gathered from three sources: Northern Shrimp Survey (2005-2008), Groundfish Stock Assessment Surveys (1996-1999), and Commercial Logbook Data (1998- 2009).

Northern Shrimp Survey

The Northern Shrimp Survey was co-sponsored by the Northern Shrimp Research Foundation and Department of Fisheries and Oceans (DFO). Surveys were conducted from late July to early September from 2005-2008 on the Fishery Products International vessel MV *Cape Ballard*. Survey design was standardized with DFO Multispecies Surveys and, therefore, followed a stratified random sampling design at depths of 100-750 m in NAFO divisions 0B and 2G.

A modified Campelen 1800 shrimp trawl with rockhopper footgear was used with a primary net and a much smaller secondary Linney Bag attached to the belly of the net which provided data on the catchability/escapability of species through the primary mesh. Each catch was sampled for shrimp and by-catch. Directed shrimp species included *Pandalus borealis* and *P. montagui*, which were sampled for maturity, weight, and enumerated. Other non-directed shrimp species, as well as groundfish and invertebrates were weighed and counted. Standardized DFO coral sampling protocols were incorporated into the survey to collect opportunistic data and samples. In 2008, sponge sampling protocols were also incorporated. All subsamples of corals and sponges were returned to DFO Newfoundland and Labrador for taxonomic verification.

The Northern Shrimp Survey data was used to model densities of corals and sponges, species richness and to provide information on location of unsuccessful sets as a proxy of extremely rough substrates, an indicator of prime coral habitat. Data collected from Linney Bag samples provided little to the density analysis due to extremely small weights; however, it did contribute to species richness.

Although based on a stratified random survey design, these data may have potential bias and limitations to its use. First of all, trawl surveys are biased by spatial coverage due to restrictions on gear use. Trawl gears are limited to 'trawlable' substrates and as a result areas with rougher substrates are under-represented in the survey. The second limitation is the potential for inconsistencies between survey years in terms of capturing all corals in a large catch, and/or accurately identifying to species especially when no sample was submitted for species verification. Finally, there may be inconsistencies with actual weights documented in the survey, especially when many pieces of the same coral colony (large gorgonian) are not all captured within an individual set. Combined with catchability issues, the by-catch weights recorded from this survey, while quantified, are suspected to be significant under-estimates of the actual *in situ* biomass. It should be noted that a large data gap currently exists due to the recent exclusion of the Voluntary Coral Protection Zone from the sampling design for the Northern Shrimp Survey.

Groundfish Stock Assessment Surveys

The second data source is from Groundfish Stock Assessment Surveys conducted by DFO. It is noted that, more recently, these surveys are referred to as Multispecies Surveys. Surveys were conducted from 1996-1999 on the *CCGS Teleost*. Survey design was standardized and followed a stratified random sampling program at depths of 123-1488 m in NAFO divisions 0B and 2G. The collection of coral data commenced December 2003. As such, coral by-catch information was not documented during this time period. However, sponge by-catch was recorded and this data was used to model densities of sponges. Sponges were not identified to

species or group and the analyses were limited to density analysis only excluding sponge species richness density modeling.

Commercial Logbook Data

The final source, Commercial Logbook data, was acquired from DFO Policy and Economics Branch, Fishery Statistics Division. Data includes statistics on three directed fisheries operating within the study area from 1998-2009, which include; northern shrimp fisheries (*Pandalus borealis*, and *Pandalus montagui*), and the Greenland halibut (*Reinhardtius hippoglossoides*) fishery. The northern shrimp fisheries used trawl gear only while the Greenland halibut fishery utilized both mobile (trawls) and fixed gears (longlines and gillnets). Commercial log book data was used as a coarse index of fishing effort through a specific time period (1998-2009) by fishery and gear types based on recorded locations of fishing activities. This data was not processed for geo-referencing errors.

Logbook data shows a bimodal distribution demonstrating directed fisheries by depth. Northern Shrimp Assessment data shows a more even distribution across depth ranges sampled (Fig. 2). For corals, it should be noted that although both the Northern Shrimp Assessment Survey data and the Commercial Logbook data occur in NAFO Divisions 2G-0B the spatial overlap of these two datasets is limited. Only 13.3% of all survey sets occurred in the same areas as the Logbook data.

CONSERVATION UNITS

Conservation units are defined as groups of species (corals and sponges) that are relatively homogeneous based on similar morphologies, general substrate preferences, and relative biomass.

Based on conclusions from the NAFO Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM) the following are accepted conservation units for corals (NAFO 2008b); sea pen fields (pennatulaceans), small gorgonians (*Acanella arbuscula*), large gorgonians (*Primnoa*, *Paragorgia*, *Keratoisis*, *Paramuricea*, *Radicipes*, etc.), Cerianthid anemone fields, antipatharians (black corals), and reef-building stony corals (*Lophelia pertusa*).

Utilizing some of these units coral species (Phylum Cnidaria) found within the study area were grouped into four units: large gorgonians, small gorgonians, sea pens, and soft corals. Soft corals are not recognized as a conservation unit in current NAFO work; however, they were incorporated in this study due to their high relative abundance and distribution in relation to the other groups. Stony corals (scleractinians) were not included due to low numbers (n=14), as well, antipatharians were not documented in survey data. See Table 1 for summary of coral counts by group and species within each group.

For this study sponge data was gathered from two time periods; groundfish survey data from 1996-1999 and Northern shrimp survey data from 2005-2008. Not all samples from the latter period were identified to species level and are only now being addressed (Fuller and Wareham unpublished data), and no sponges were identified beyond Phylum for the groundfish surveys. For this reason sponges are grouped as one conservation unit, but are accepted as an appropriate unit based on biomass as concluded by ICES (2009). Most sponges can be found broadly distributed at low densities, and when found at high densities the majority of the species are composed of *Geodia* spp., which are large ball-shaped sponges that can measure up to 50 cm high and weigh 10's of kilograms per animal (Bruntse and Tendal 2001). When sponges are

concentrated in dense aggregations, particularly *Geodia*, they are referred to as 'sponge grounds' and are considered highly vulnerable to benthic fishing practices and gear types. Refer to Table 1 for a summary of sponge counts used in the analyses.

DENSITY ANALYSIS

Density analysis used by-catch data from research vessel surveys (Northern Shrimp Stock Assessment Survey, Groundfish (=Multipsecies) survey) to calculate and map the spatial distribution of areas of significant coral and sponge catches in NAFO divisions 2G-0B. The surveys took place between 2005 and 2008 and recorded data from 974 fishing sets. For corals, there were 634 sets that caught 19 different species of coral and there were 340 sets that did not catch any corals. For sponges, there were 337 sets that caught sponges; 287 from Northern Shrimp Survey data (2005-2008) and 50 sets from Groundfish Surveys (1996-1999).

Data was modeled using the methodology from Kenchington et.al. (2009). Using these methods, density analysis was used to calculate and map the areas of significant coral and sponge by-catches. Kernel density analysis was used to create a series of polygons representing varying levels (densities) of catch biomass and species richness. The data was then analyzed to determine how the areas of the bounding polygons changed with increasing by-catch weight thresholds. The bounding polygon that showed the greatest percentage change in area represented the significant catch area. It is noted that this does not necessarily encapsulate all ecologically significant concentrations. For further details on this methodology refer to Kenchington et.al. (2009).

Data was imported from spreadsheets into ArcGIS (ESRI Canada Limited) and plotted using the average of the start and end latitudes and longitudes. Data was then classified according to the five species groups: large and small gorgonians, sea pens, soft corals and sponges to facilitate analysis for species of similar biological characteristics.

The first step in the analysis was to perform the density analysis using the Kernel Density tool in ArcGIS. Kernel Density creates an interpolated surface by calculating the density of features (e.g. coral biomass) in a circular neighborhood around those features. This function inputs a search radius and outputs a cell size. The search radius represents the size of the area in which to look for neighboring points. This radius must be chosen such that the model creates a near-continuous surface yet does not obscure the trends in the data. Kernel Density analysis was done for each species grouping using search radii of 5, 10, 15, 20, 25 and 30 km. With the exception of the soft corals, all density surfaces that were created with a search radius of 20 km or less were too patchy. These radii did not extend far enough to create a surface and many points did not find any neighbors at all. Surfaces that were generated using the 30 km radius tended to smooth out the highest density areas. Therefore, the search radius for this analysis was chosen at 25 km as the surfaces created were near-continuous yet did not smooth out the data and preserved the underlying physical features.

The output raster cell size was chosen at 500 m x 500 m as this resolution produced smooth maps. Density surfaces representing catch weight per square kilometer were created for large and small gorgonians, sea pens and soft corals. Stony corals were not modeled as there were not enough data points (n=14). After the density surfaces were created, contour lines were calculated using the ArcGIS Contour function. The contour intervals varied for each of the species groupings and were chosen to map the smallest catch values recorded and ranged from 0.0001 to 0.000001 kg / km^2. These contour lines were then converted into polygons using the 'Feature To Polygon' function in ArcGIS.

The next step made use of quantile analysis to select weight thresholds to process against the density polygons. Quantile classification sorts and ranks the data and produces classifications of unequal sized intervals so that there are an equal number of points in each interval. Eight quantile breaks were calculated for each species group. Quantile analysis was used to ensure that an area calculation for an arbitrary threshold was not biased by a single value.

For each of the eight classification splits a point-in-polygon intersection analysis was performed between the catch data and the density polygons to identify the polygons that were spatially co-incident with the catch data points. These polygons were then merged to create a single region that represented the minimum bounding polygon for that catch weight threshold. It is the areas of these polygons that were used to determine the significant catch weight values.

RESULTS AND DISCUSSION

DENSITY ANALYSIS OF CORALS AND SPONGES

Density analysis of all corals and sponges were mapped along with polygons delineated as 'significant areas' based on threshold values determined for each conservation unit. As stated in Kenchington et al. (2010) taxonomic uncertainty is not critical in this analysis since the analysis are based on groups at a higher taxonomic level and not by individual species.

Unlike the NAFO process, buffer zones were not considered at this point but will need to be addressed at a management level - particularly for controversial areas where fishing and significant areas overlap. Results and discussions are presented below by conservation units with all figures (maps and table) in Appendix 1.

Large Gorgonians

The kernel density map for large gorgonians is illustrated in Figure 3. Based on results of the density analysis five areas with significant catches emerged using a threshold of 20 kg; two large areas and three much smaller areas (Fig. 4). All areas were located either on Saglek Bank or within Hatton Basin, with the highest concentrations located in the northern portion of Hatton Basin in NAFO division 0B.

It should be noted that catch weights for large gorgonians could be greatly underestimated due to the trawl catchability of this group. Most samples consisted of small fragments of branch tips of what would be normally morphologically large colonies such as *Primnoa resedaeformis*, and *Paragorgia arborea*. The same rational was used for choosing a 90% quantile for significant catches for large gorgonians by the WGEAFM (NAFO 2008b).

Off Newfoundland and Labrador, the greatest occurrence and abundance of *Primnoa resedaeformis*, and *Paragorgia arborea* in particular, were found in Hatton Basin and on the northern portion of Saglek Bank (Wareham and Edinger 2007; Wareham 2009). See Figures 5 and 6 for examples of large catches of coral and sponge by-catch photographed from Hatton Basin.

Small Gorgonians

The kernel density map for small gorgonians is illustrated in Figure 7. Based on results of the density analysis four areas emerged with significant catches using a threshold of 0.04 kg (Fig. 8). Concentrations are located off Southeast Baffin Shelf, as well as further south off the outer edge of Saglek Bank.

It is noted that sampling efficiency for small gorgonians will be very low due to the lower catchabilty of this group by trawl gear in comparison to the larger gorgonians. This is due to their low height above the seabed relative to the height above-bottom of the trawl net opening.

Sea Pens

The kernel density map for sea pens is illustrated in Figure 9. Based on results of the density analysis 10 small areas emerged with significant catches using a threshold of 0.04 kg (Fig. 10). The highest concentrations are located on the northeast portion of Southeast Baffin Shelf, within Hatton Basin, and on the edge of Saglek Bank.

Soft Corals

The kernel density map for soft corals is illustrated in Figure 11. Based on results of the density analysis, soft corals have the greatest spatial coverage of significant catches using a threshold of 0.04 kg (Fig. 12). The largest concentrations are located on Okak Bank. It is also noted that, amongst coral groups, soft corals show the greatest spatial distribution and the greatest number of significant areas. Even though soft corals are not currently recognized as conservation unit (NAFO 2008b) knowledge of their distribution as well as areas of significant concentrations could be useful when delineating representative areas for Marine Protected Areas (MPA) status.

Sponges

The kernel density map for sponges (all species combined) is illustrated in Figure 13. The analysis identified two potential thresholds; 6.3 kg (% area change 3x) and 115 kg (% area change 2.9x). Although the percentage changes were similar the resulting significant catch polygons were markedly different (~49,000 km^2).

Based on results of the density analysis, spatial distributions of significant catches using a threshold of 6.3 kg are shown in Figure 14. The highest concentrations were widely distributed throughout the study area primarily towards the edge of the continental shelf. Sponges had the highest densities as well as number of significant areas for all groups. When using a much higher threshold value of 115 kg significant concentrations contracted to an area within as well as around Hatton Basin (Fig. 15).

In summary, for the density analysis, significant catches for all groups (corals and sponges), for their respective thresholds, are shown in Figure 16 for corals and Figure 17 for sponges. The distribution of large gorgonians are confined to the Hatton Basin and the northern portion of Saglek Bank, while the distribution of significant soft coral catches are primarily confined to the shelf. Small gorgonians and sea pens are found in slope environments. While sponges are, for the most part, found in close proximity to Hatton Basin as well as along the continental edge and slope.

FISHING EFFORT

A coarse index of fishing effort by fisheries and gear types is illustrated in Figures 18 to 20. The northern shrimp fishery directed for *Pandalus montagui* targeted waters (average depth 167 m) in close proximity to Hudson Strait while the directed fishery for *Pandalus borealis* targeted waters (average depth 185 m) surrounding Hatton Basin and along the outer continental break of both Southeast Baffin Shelf and Labrador Shelf (Fig. 18). In contrast, the Greenland halibut fishery targeted, almost exclusively, deeper waters (average depth 533 m) along the edge of Southeast Baffin and Labrador Shelves (Fig. 19). Mobile and fixed gears are utilized in this fishery with gillnets primarily targeting northern areas, longlines more to the south, and trawls intermixed. When both shrimp and Greenland halibut fisheries are mapped by gear classes (Fig. 20), it is apparent that, fixed gears are deployed in deeper water compared to mobile gears.

SPECIES RICHNESS

Coral species richness, defined as the number of species captured per survey set, is shown in Figure 21. Highest values were found in and around the Hatton Basin, as well as along the shelf edge. Maximum number of species found per survey set was eight. See Figure 22 for a histogram of the frequency distribution of the number of coral species captured for all sets.

OVERLAY MAP OF SPECIES RICHNESS, SIGNIFICANT AREAS AND TRAWL TEAR-UPS

When all data from various sources are compiled into one overview map, several patterns emerge. Two maps were produced to illustrate these patterns. The first used a sponge significant area threshold of 6.3 kg overlaid with coral significant areas, coral species richness, and survey tear-ups. The major pattern that emerges is an area surrounding Hatton Basin showing highest species richness overlying significant areas for all groups (Fig. 23). In addition, trawl tear-ups, indicative of rough terrain, largely corresponded with areas of high coral species richness and significant areas. When using the higher threshold for sponges (115 kg), while the significant areas for sponges have spatially contracted, the patterns appear to hold (Fig. 24).

SUMMARY AND CONCLUSIONS

This study attempted to relate the spatial distribution of commercial fishing effort with the density analyses of corals and sponges in NAFO divisions 2G-0B near Hatton Basin. However, this assessment was largely precluded by the lack of any sufficient overlap between the two datasets. Significant areas may exist in commercially fished areas; however, the data currently does not exist to perform this analysis.

Results show that significant catches of large gorgonians, sea pens, and sponges were found in the vicinity of Hatton Basin. Large gorgonians and sea pens occurred mostly in slope environments around Hatton Basin and along the Labrador Shelf edge, while soft corals occurred primarily on the shelf. Although soft corals were not recognized as a NAFO conservation unit, significant concentrations, such as those found on Saglek Bank, may be indicative of important habitats.

Based on the density analyses for corals and sponges, coral species richness, and significant catches for large gorgonians, Hatton Basin and adjacent areas emerged as biologically important locations. In addition, set tear-ups were used as a proxy for very rough substrates.

When these data were mapped there appeared to be a relationship with the areas of high coral species richness and significant catch polygons.

Although Hatton Basin is biologically interesting in relation to corals and sponges, this area still remains under-surveyed. A significant data gap currently exists due to the recent exclusion of the Voluntary Coral Protection Zone from the sampling design for the Northern Shrimp Survey. Increased data from this area would provide a better understanding of the true nature of coral and sponge habitats within Hatton Basin. Non-intrusive sampling (e.g. Remotely Operated Vehicle, Autonomous Underwater Vehicle), rather than traditional trawl surveys, should be explored to further our knowledge of this area.

ACKNOWLEDGEMENTS

Special thanks to Dr. Ellen Kenchington and her team (C. Lirette and A. Cogswell) from the Bedford Institute of Oceanography, Fisheries and Oceans for their support and guidance throughout this project. We wish to thank Beth Hiltz, Tim Siferd, and Margaret Treble from Fisheries and Oceans, Freshwater Institute (Winnipeg, MB) for their support. We wish to thank all sea-going personnel from the Canadian Coast Guard Ship (CCGS) *Teleost*, CCGS *Wilfred Templeman*, and Research Vessel (RV) *Cape Ballard* for their cooperation and contributions towards this project. Special thanks to DFO staff P. Veitch and D. Orr for their invaluable data contributions. We thank Nadine Templeman for her assistance with editing and formatting. Finally, we wish to thank the Department of Fisheries and Oceans Science Branch, Newfoundland & Labrador region, for providing logistical support.

REFERENCES

Bruntse, G., and Tendal, O.S. 2001. Marine biological investigations and assemblages of benthic invertebrates from the Faeroe Islands. Kaldbak Marine Biological Laboratory (Faroe): 1-42.

DFO. 2009. Development of a framework and principles for the biogeographic classification of Canadian marine areas. DFO Canadian Science Advisory Secretariat. Science Advisory Report 2009/056, 17pp.

FAO. 2009. Report of the Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the high Seas. Rome, 4-8 February and 25-29 August 2008. ftp://ftp.fao.org/docrep/fao/011/i0605t/i0605t00.pdf.

Gass, S. E., and Willison, J. H. M. 2005. An assessment of the distribution of deep-sea corals in Atlantic Canada by using both scientific and local forms of knowledge. In A. Freiwald, J.M. Roberts (Eds.), *Cold-water corals and ecosystems* (pp. 223-245). Springer-Verlag, Heidelberg.

Gilkinson, K., and Edinger, E. (Eds.). 2009. The ecology of deep-sea corals of Newfoundland and Labrador waters: biogeography, life history, biogeochemistry, and relation to fishes. (pp. 4-22). Canadian Technical Report of Fisheries and Aquatic Sciences No. 2830: vi + 136 p.

ICES. 2009. Report of the ICES-NAFO Joint Working Group on Deep Water Ecology (WGDEC), 9-13 March 2009, ICES CM 2009\ACOM:23 94 pp.

Kenchington, E., Cogswell, A., Lirette, C, and Murillo-Perez, F. J. 2009. The use of density analysis to delineate sponge grounds and other benthic VMEs from trawl survey data. NAFO SCR Doc. 09/6.

Kenchington, E., Lirette, C., Cogswell, A., Archambault, D., Benoit, H., Bernier, D., Brodie, B., Fuller, S., Gilkinson, K., Levesque, M., Power, D., Siferd, T., Treble, M., and Wareham, V. 2010. Delineating Coral and Sponge Concentrations in the Biogeographic Regions of the East Coast of Canada Using Spatial Analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/nnn, vi + 211 pp. (In prep.)

MacIsaac, K., Bourbonnais, C., Kenchington, E., Gordon Jr. D., and Gass, S. 2001. Observations on the occurrence and habitat preference of corals in Atlantic Canada. In J.H.M. Willison, J. Hall, S.E. Gass, E.L.R. Kenchington, M. Butler, and P. Doherty (Eds.), *Proceedings of the First International Symposium on Deep-Sea Corals* (pp. 58-75). Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia.

MPA News. 2007. Canadian trawlers designate voluntary coral closure; fisheries management calls it"good first step: MPA News 9:2.

NAFO. 2008a. Report of the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WGEAFM). NAFO Scientific Council Summary Document 08/10, Serial No. N5511, 70pp.

NAFO. 2008b. Report of the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WGEAFM). NAFO Scientific Council Summary Document 08/24, Serial No. N5592, 19pp.

Wareham, V. E. 2009. Update on deep-sea coral distributions in the Newfoundland Labrador and Arctic regions, Northwest Atlantic. In K. Gilkinson, and E. Edinger (Eds.), *The ecology of deep-sea corals of Newfoundland and Labrador waters: biogeography, life history, biogeochemistry, and relation to fishes.* (pp. 4-22). *Canadian Technical Report of Fisheries and Aquatic Sciences* No. 2830: vi + 136 p.

Wareham, V. E. 2010. Identification, distribution, and conservation of deep-sea corals in Canada's Northwest Atlantic. M.Sc. Thesis, Memorial University, St. John's, NL., Canada, unpublished.

Wareham, V. E., and Edinger, E. N. 2007. Distributions of deep-sea corals in the Newfoundland and Labrador region, Northwest Atlantic Ocean. *Bulletin of Marine Science 81*(Supp. 1), 289-312.

APPENDIX 1: TABLES AND FIGURES

Table 1. Summary of species counts by conservation unit.

Conservation Units	Species		Count
Large Gorgonians	*Primnoa resedaeformis*		53
	Paragorgia arborea		27
	Paramuricea spp.		11
	Gorgonian sp.		3
	Acanthogorgia armata		2
		Total	96
Sea Pens	*Halipteris finmarchica*		20
	Sea pen spp.		12
	Pennatula grandis		8
	Anthoptilum grandiflorum		5
	Umbellula lindahli		4
	Funiculinia quadrangularis		1
		Total	50
Small Gorgonians	*Acanella arbuscula*		74
	Anthothela grandiflora		11
		Total	85
Soft Corals	Neptheid spp.		207
	Gersemia rubiformis		96
	Duva florida		64
	Anthomastus spp.		22
		Total	389
Stony Corals	*Flabellum alabastrum*		11
	Flabellum angulare		3
		Total	14
Sponges	Sponge spp.		337
		Total	337

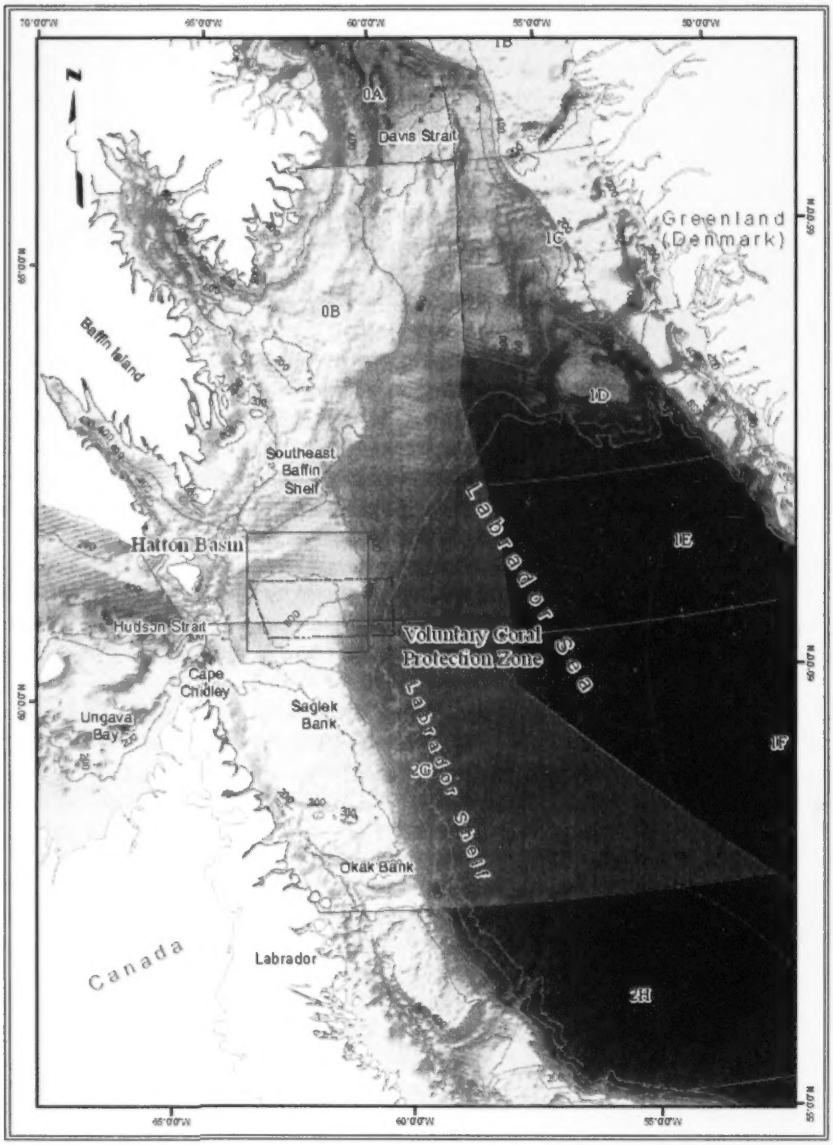

Figure 1. Map of study area highlighting bathymetric features of Hatton Basin and surrounding area.

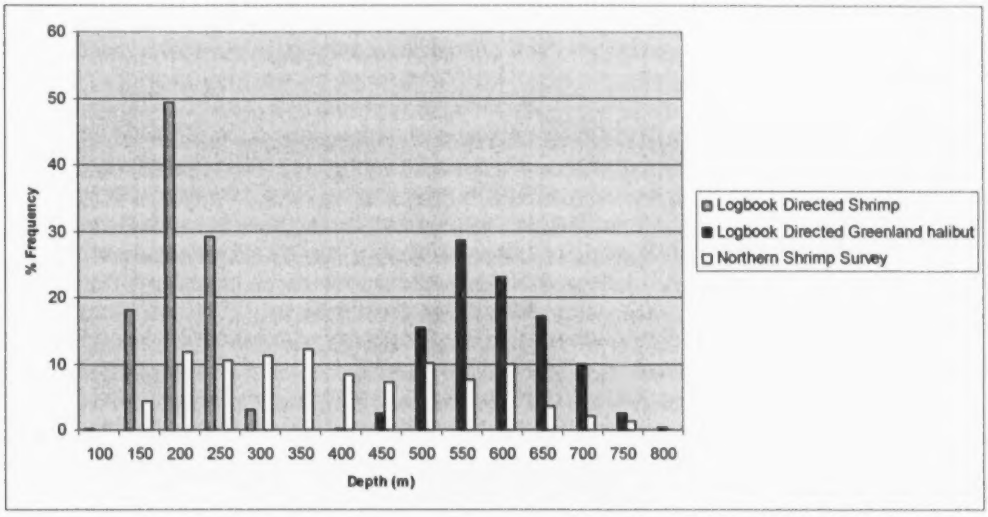

Figure 2. Histogram of data sources by depth.

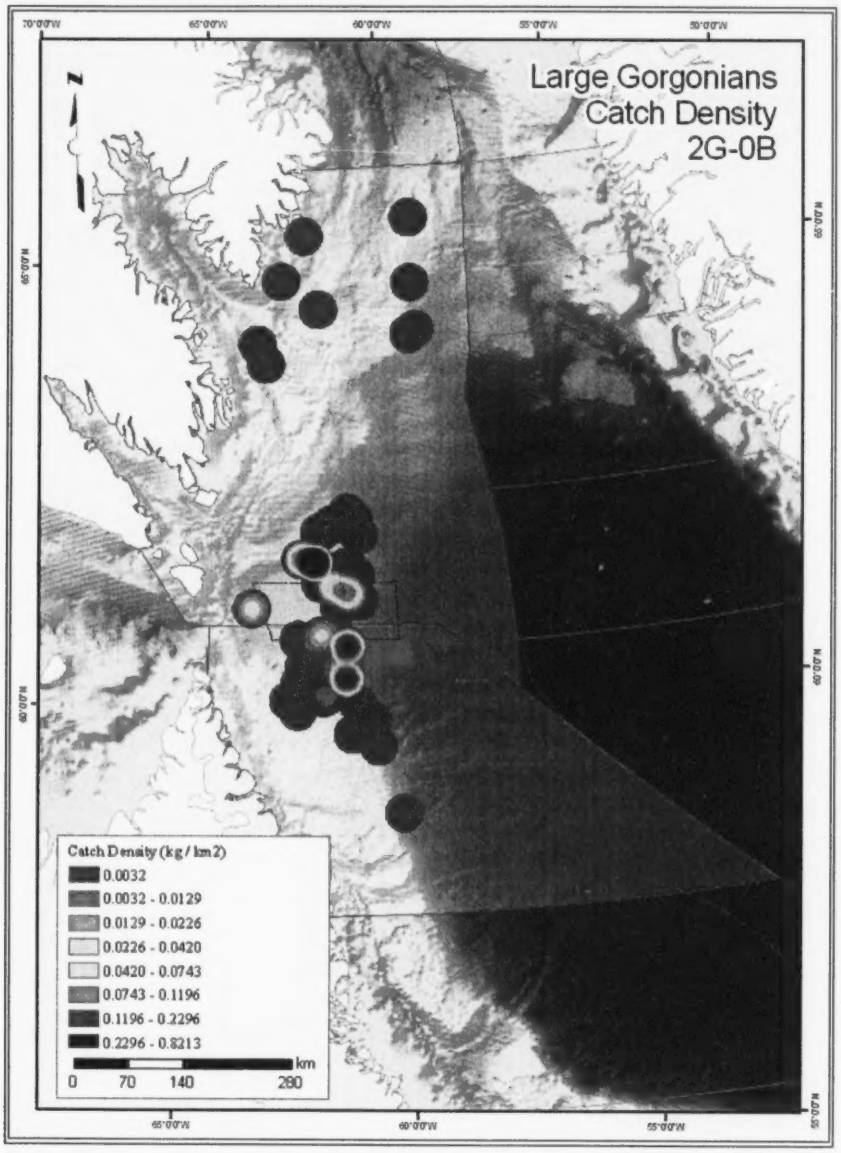

Figure 3. Kernel density analysis of large gorgonians (2G-0B).

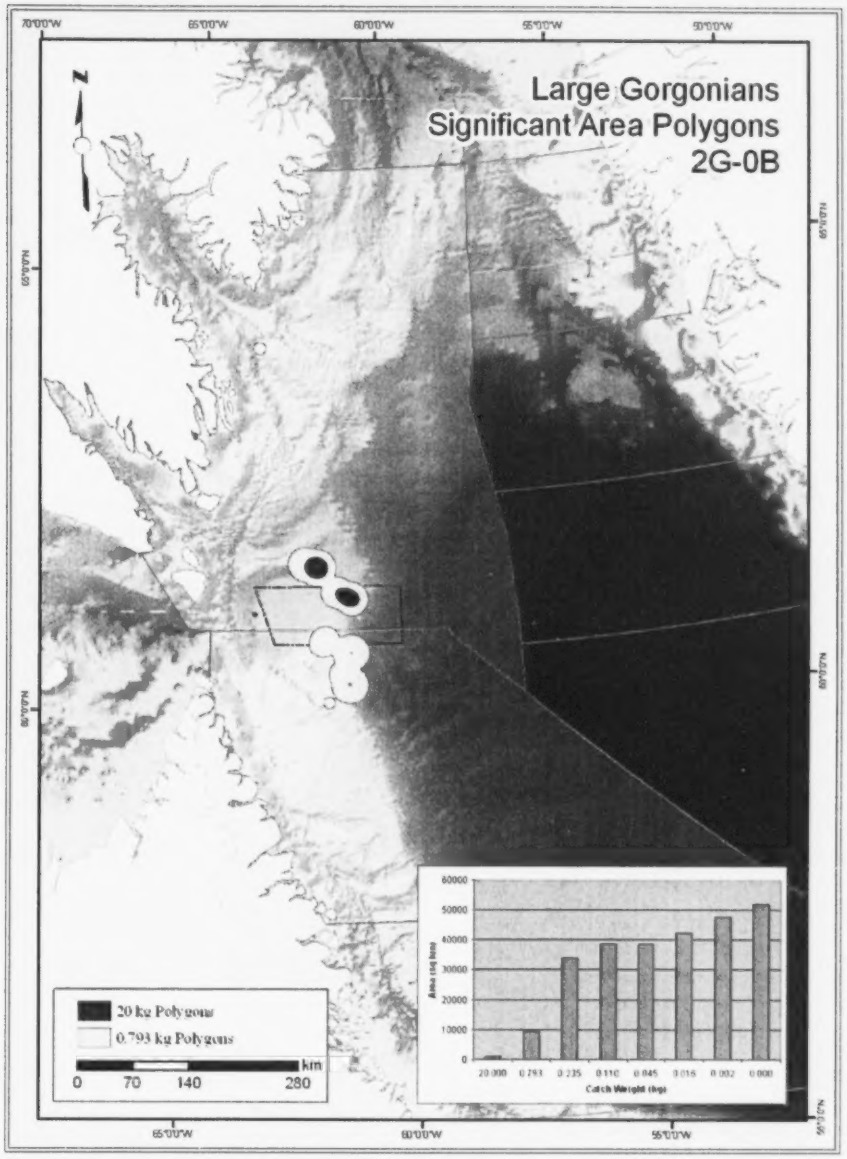

Figure 4. Significant area polygons of large gorgonians (2G-0B)

Figure 5. By-catch of corals (Paragorgia arborea) and sponges captured from one set conducted during the Northern Shrimp Survey (2006) in Hatton Basin. Photo courtesy of DFO, 2006.

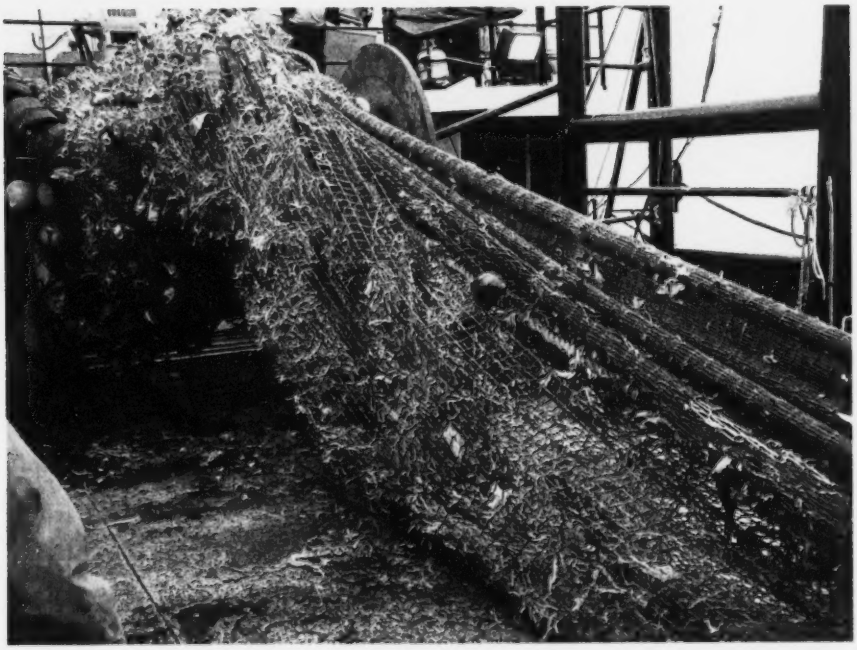

Figure 6. By-catch of coral (Primnoa resedaeformis) entangled in a commercial Otter Trawl targeting Greenland halibut in Hatton Basin (2006). Photo courtesy of Fisheries Observer Program, 2006.

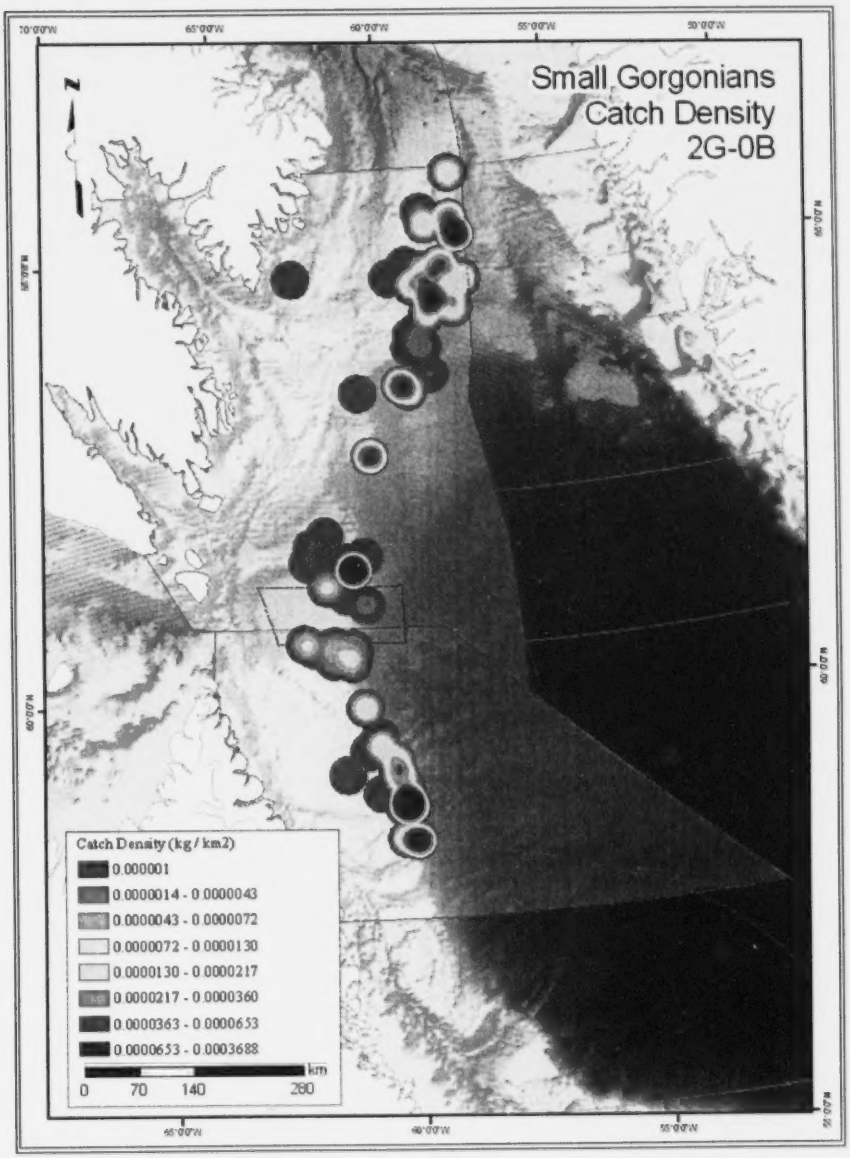

Figure 7. Kernel density of small gorgonians (2G-0B).

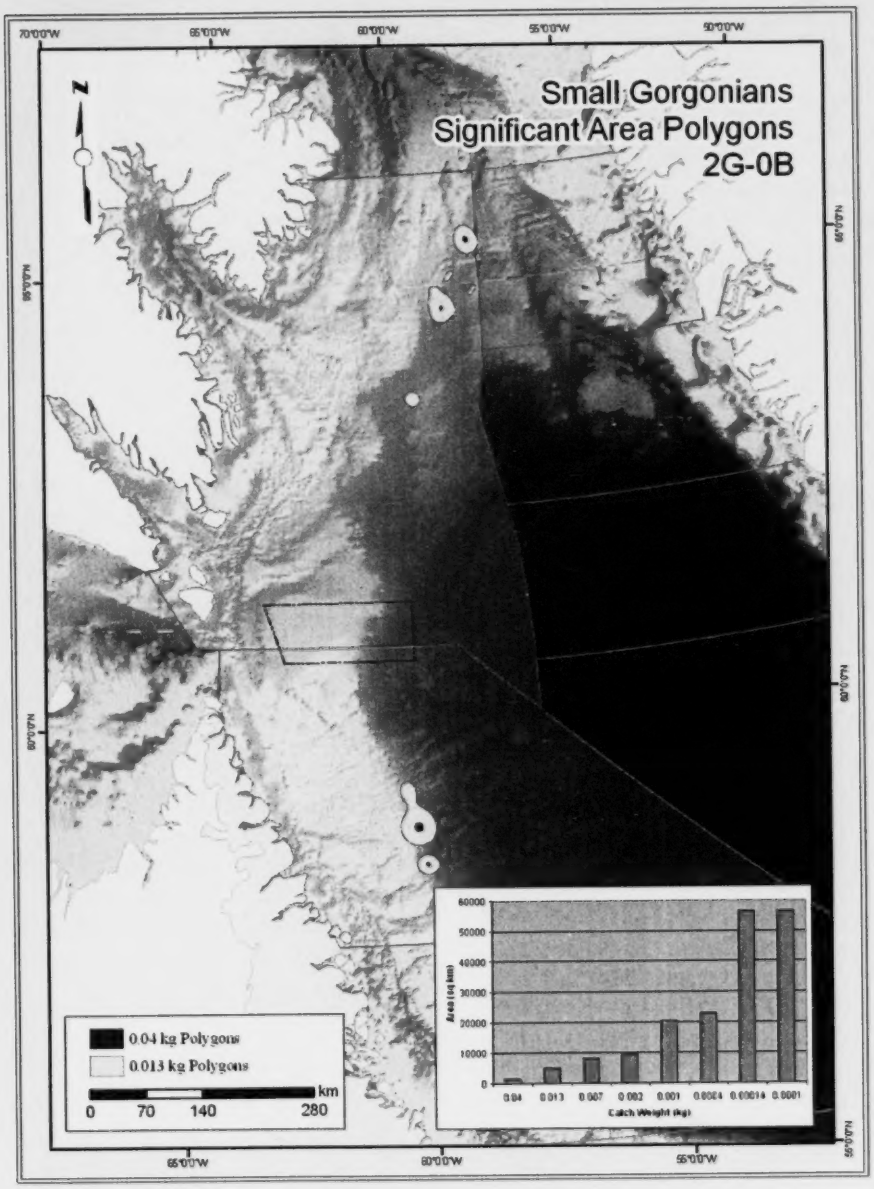

Figure 8. Significant area polygons of small gorgonians (2G-0B).

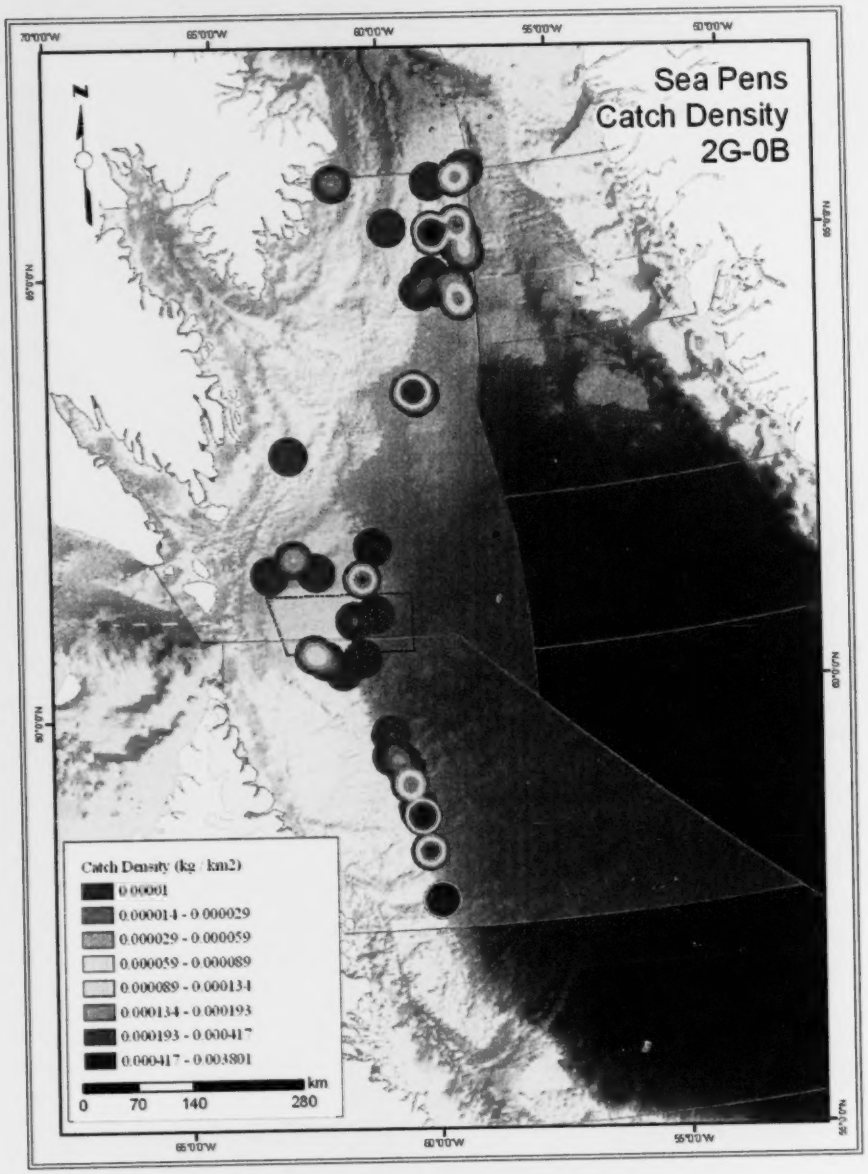

Figure 9. Kernel density of sea pens (2G-0B).

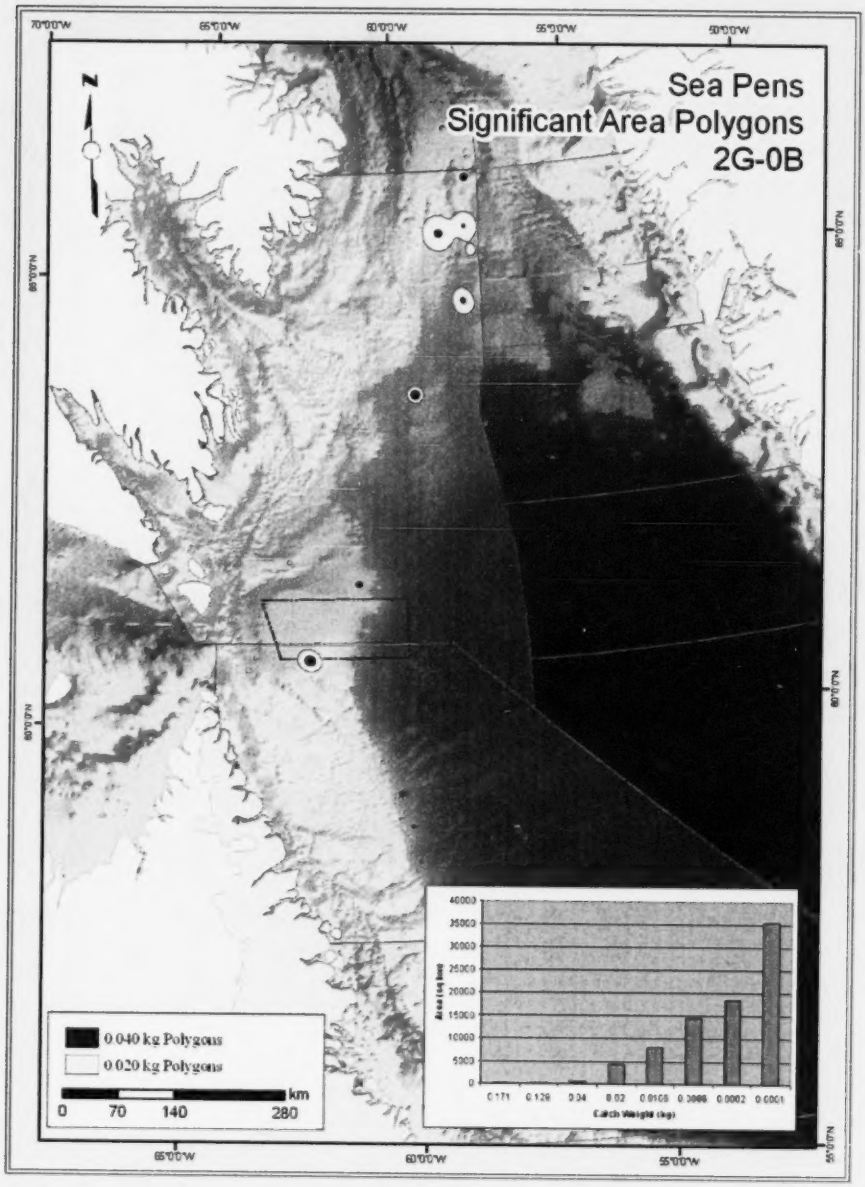

Figure 10. Significant area polygons of sea pens (2G-0B).

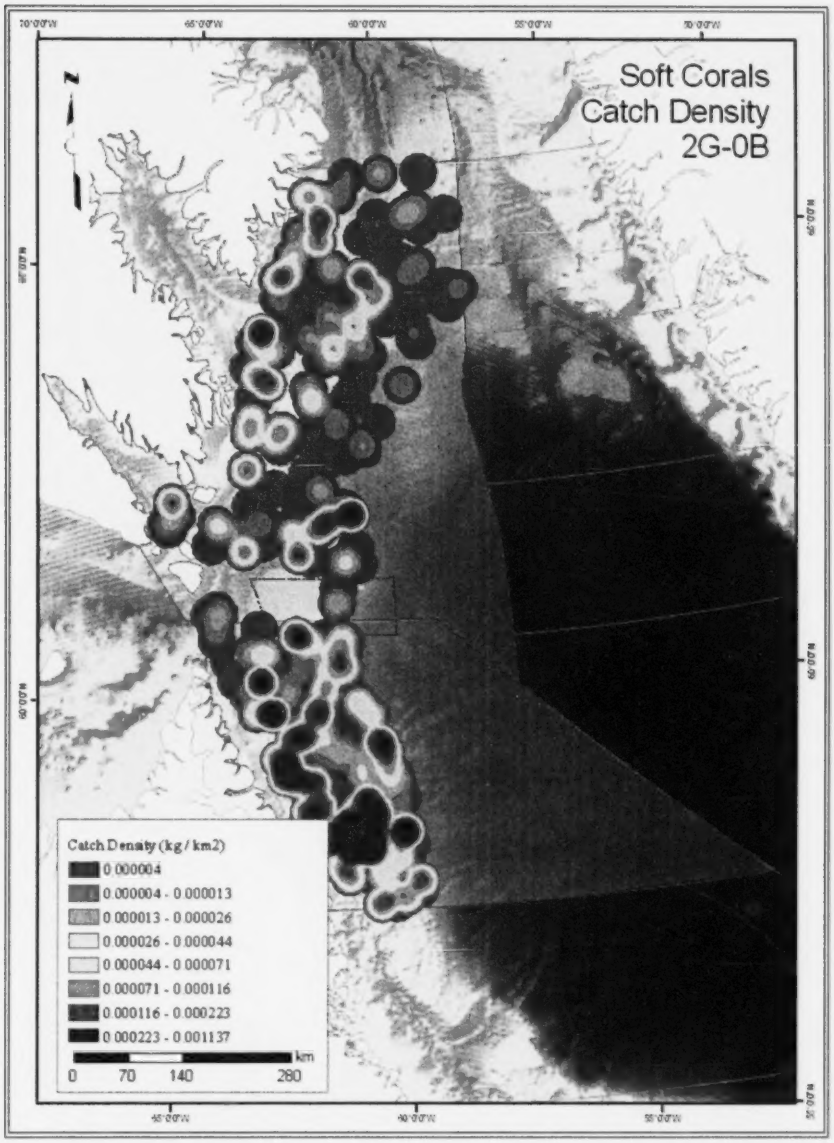

Figure 11. Kernel density of soft corals (2G-0B).

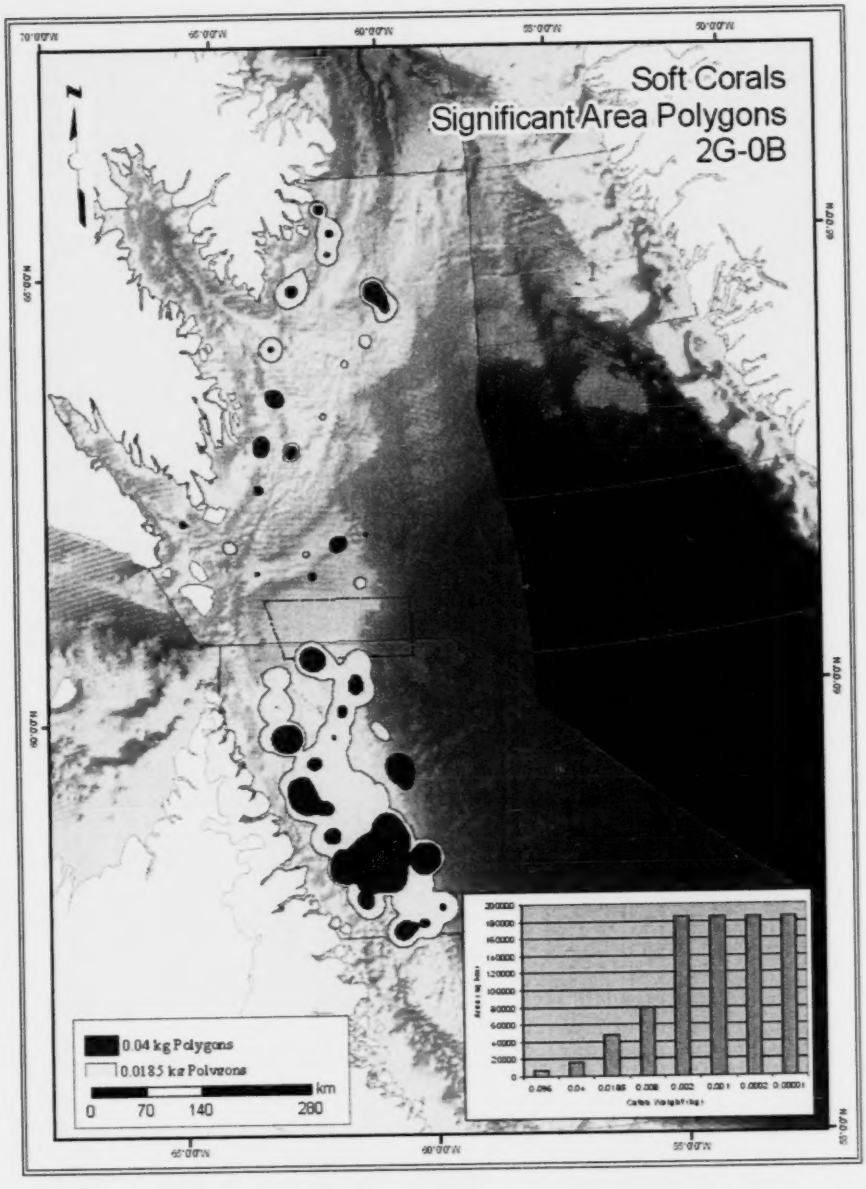

Figure 12. Significant area polygons of soft corals (2G-0B).

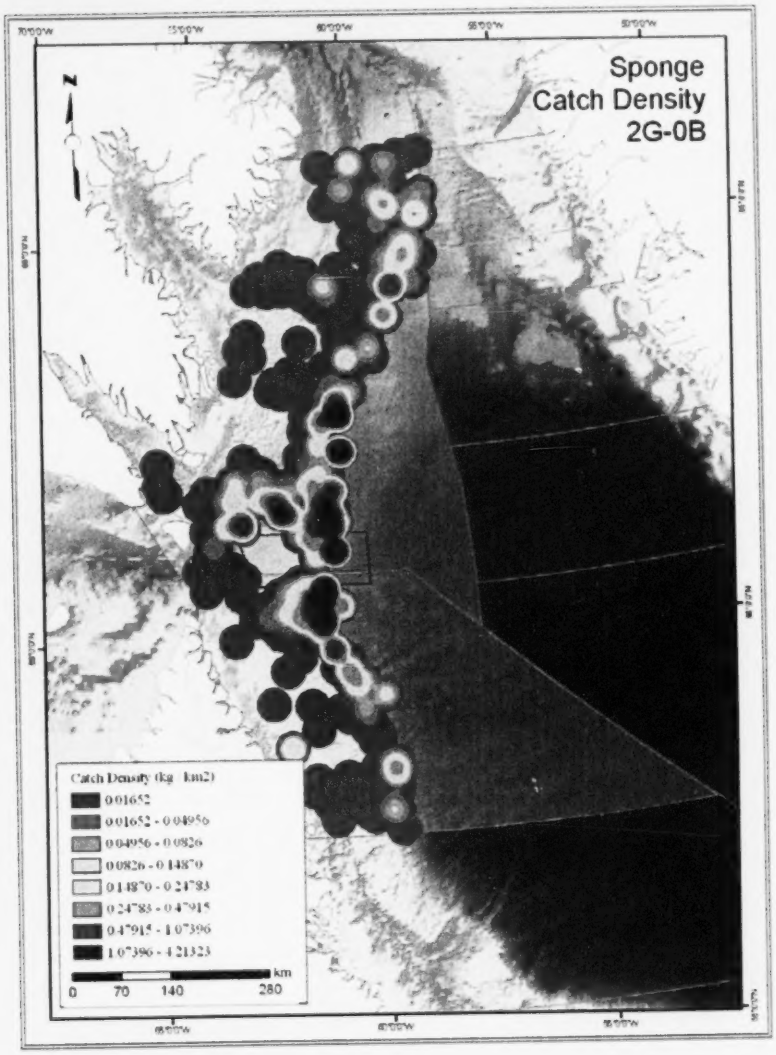

Figure 13. Kernel density of sponges (2G-0B).

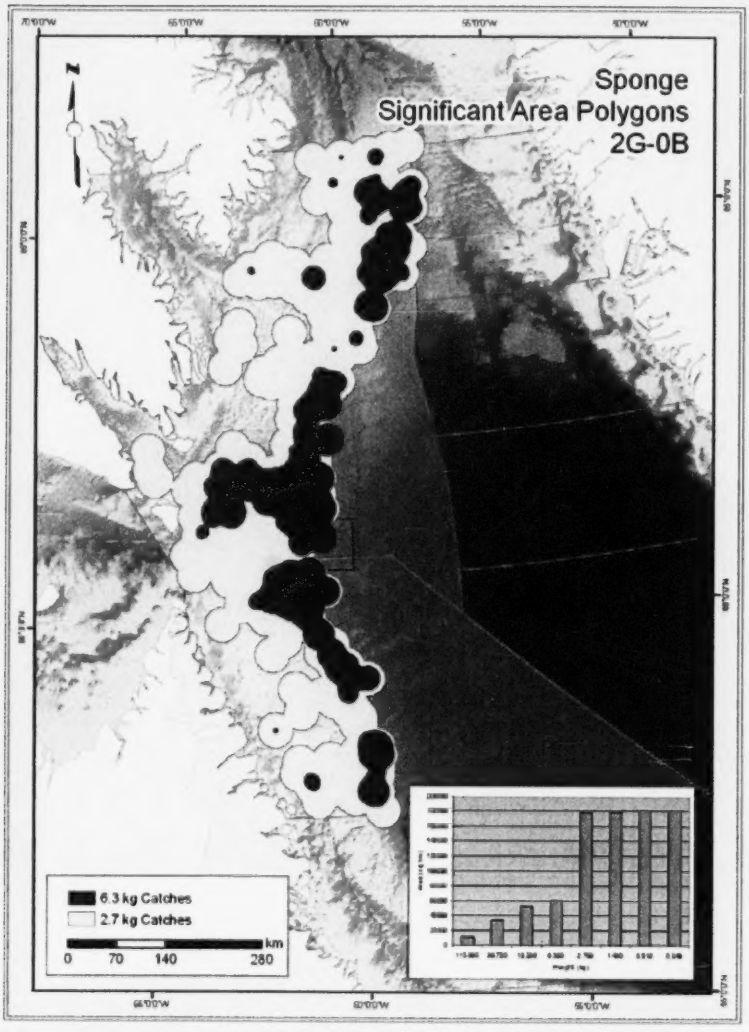

Figure 14. Significant area polygons of sponges using 6.3 kg threshold (2G-0B).

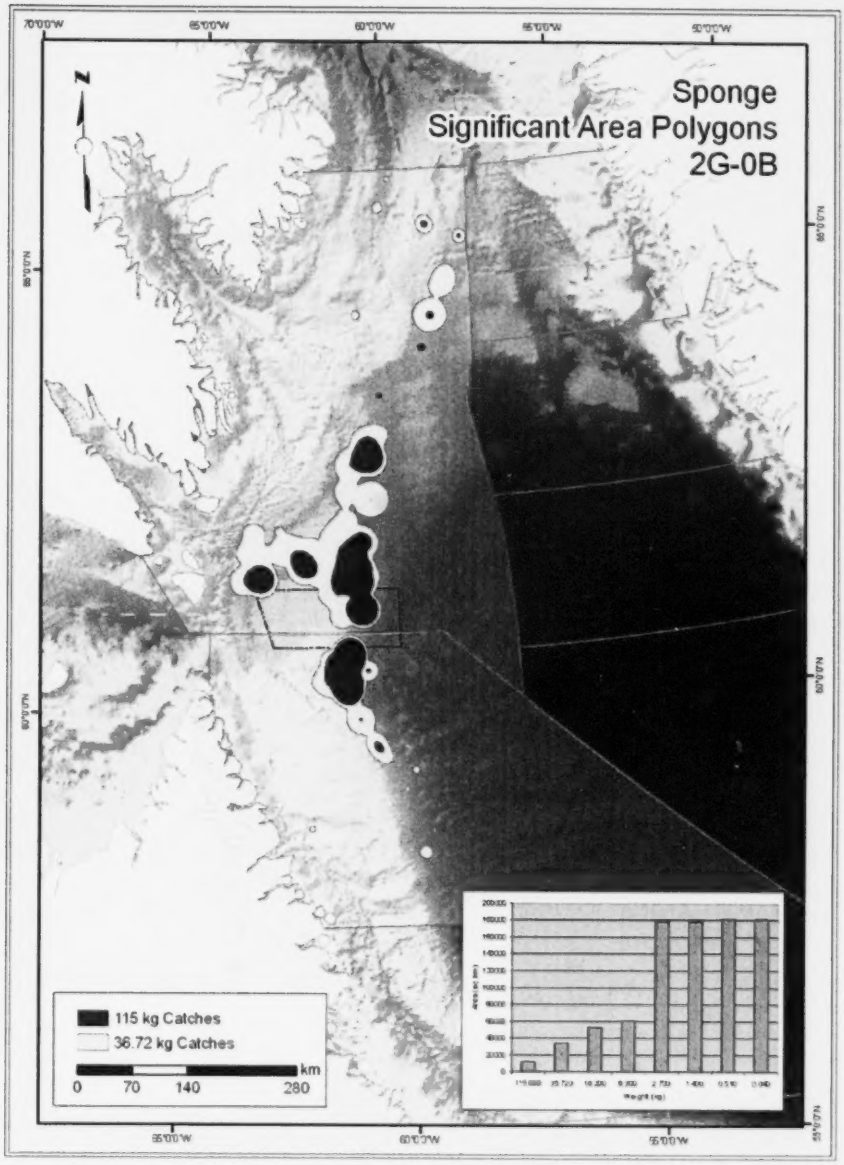

Figure 15. Significant area polygons of sponges using 115 kg threshold (2G-0B).

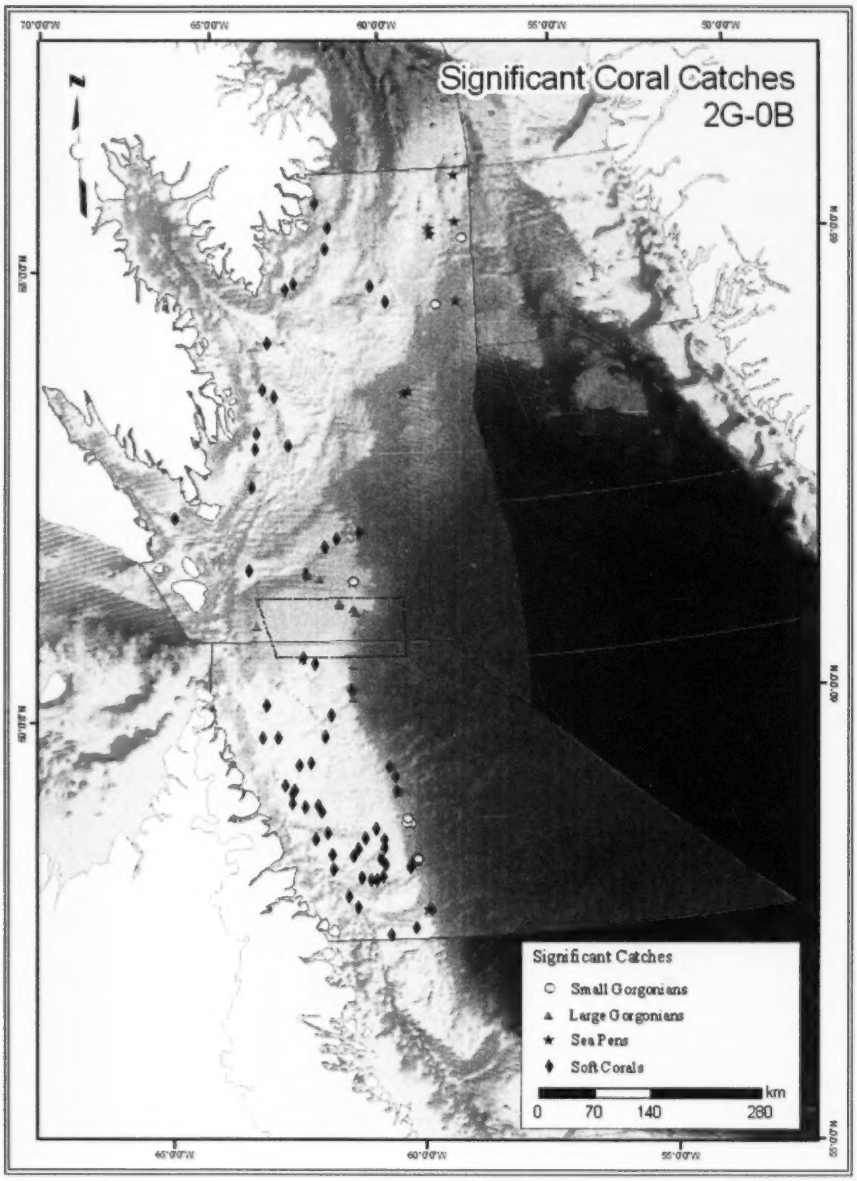

Figure 16. Significant catch locations of all coral conservation units.

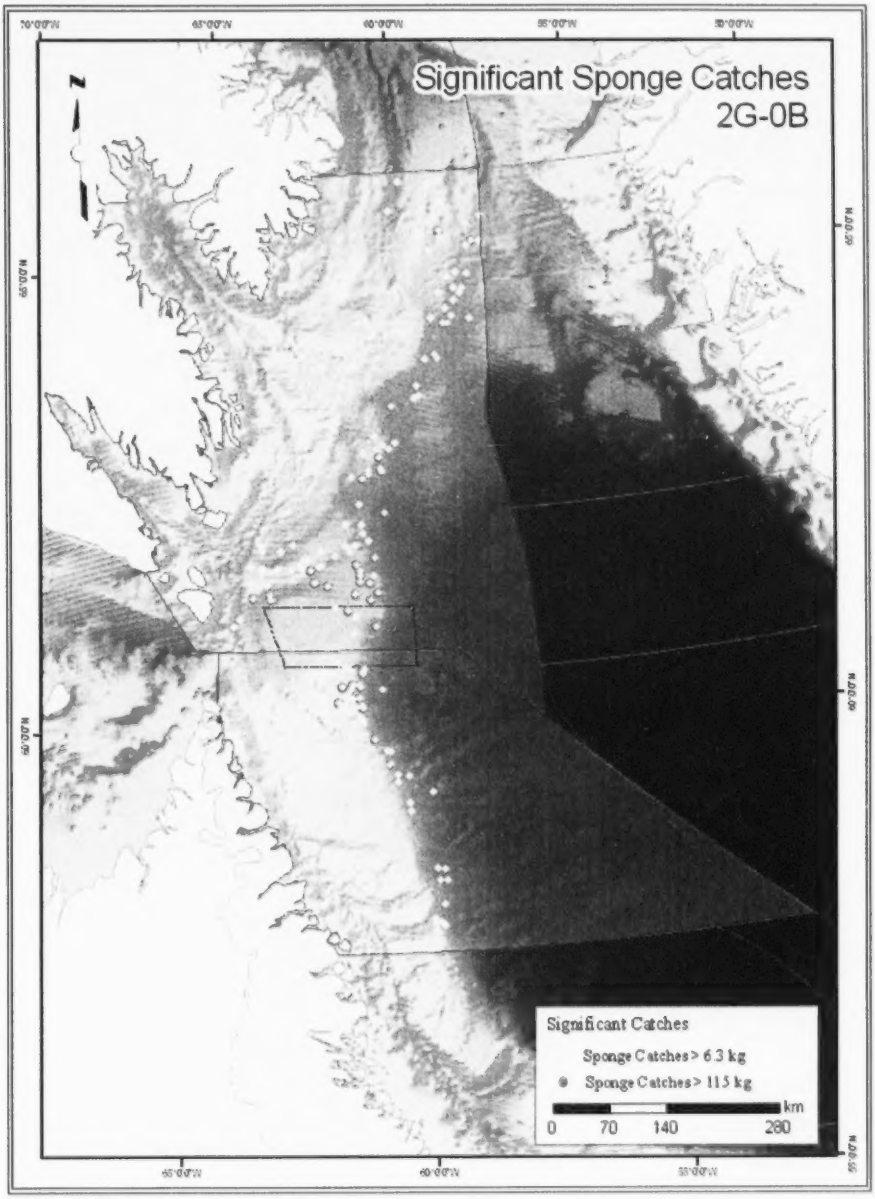

Figure 17. Significant catch locations of sponge conservation units using two thresholds (6.3 kg and 115 kg).

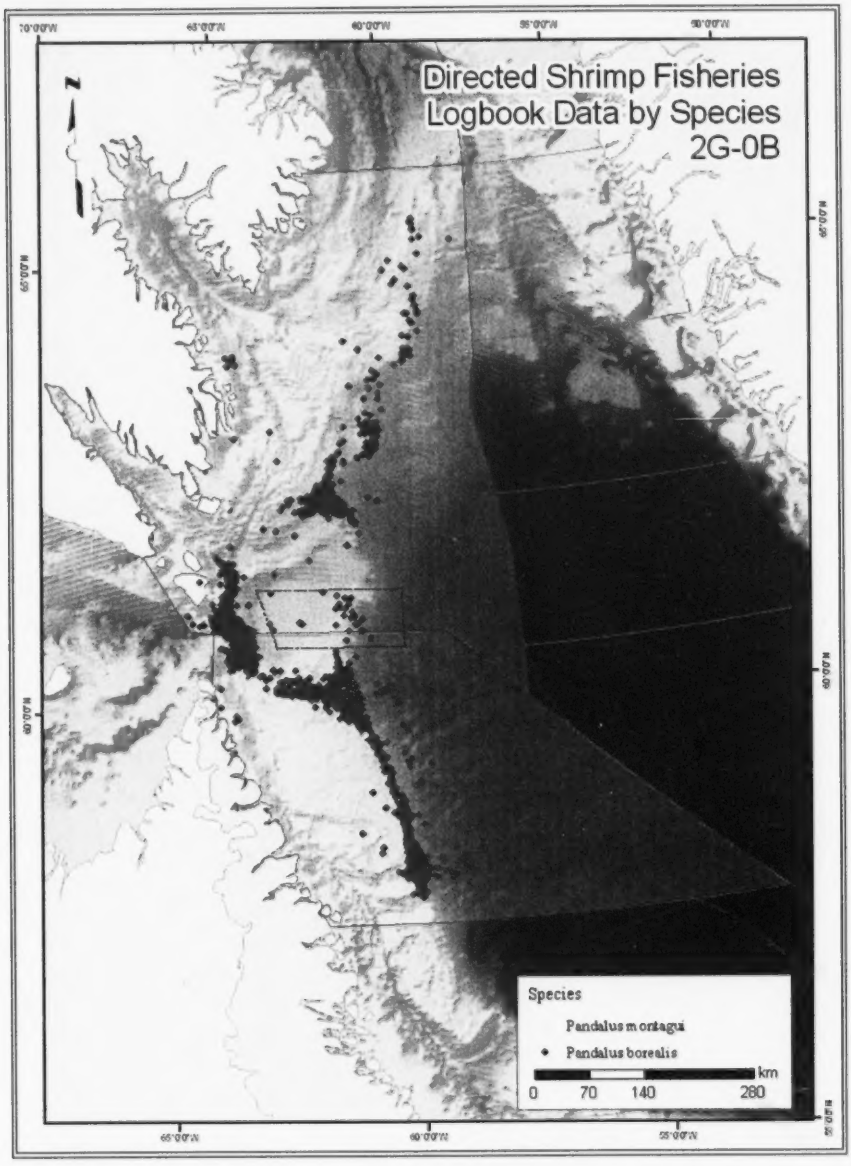

Figure 18. Logbook data for northern shrimp fisheries directed for Pandalus montagui, and Pandalus borealis (2G-0B).

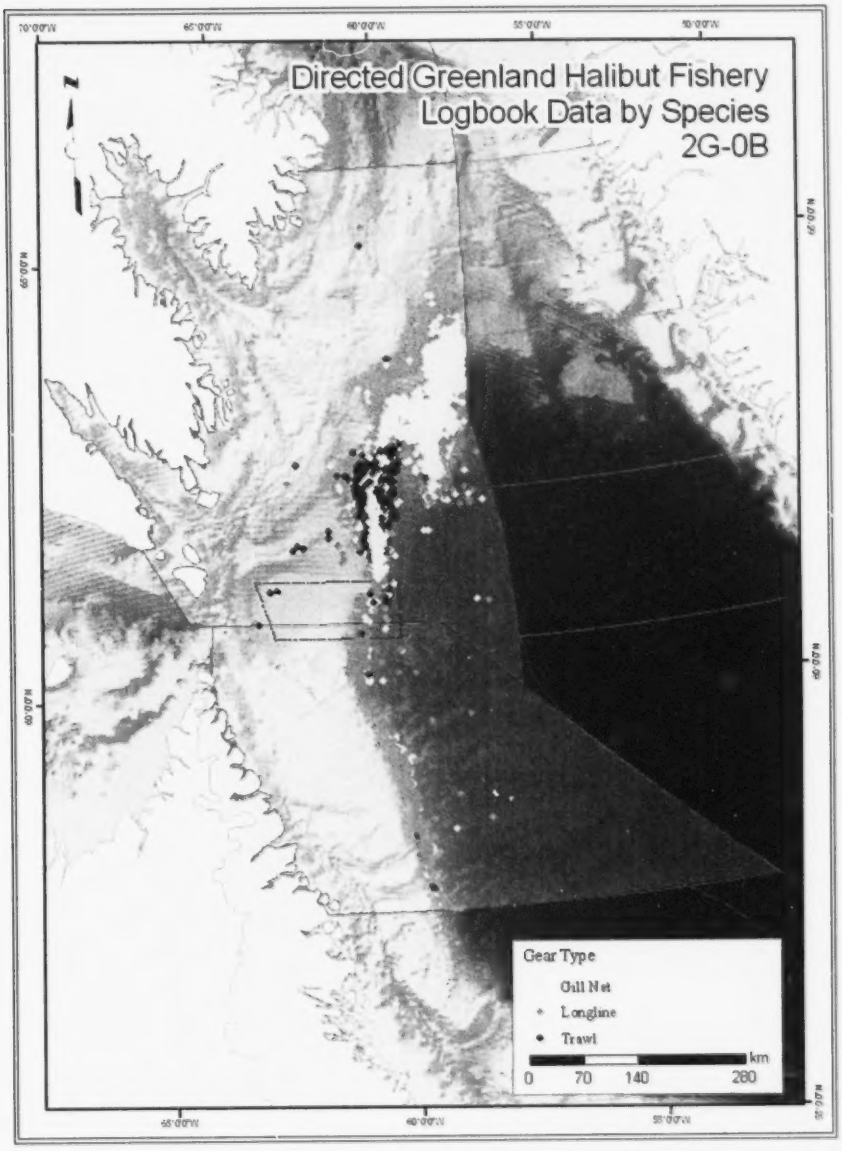

Figure 19. Logbook data directed for Greenland halibut by gear types (2G-0B).

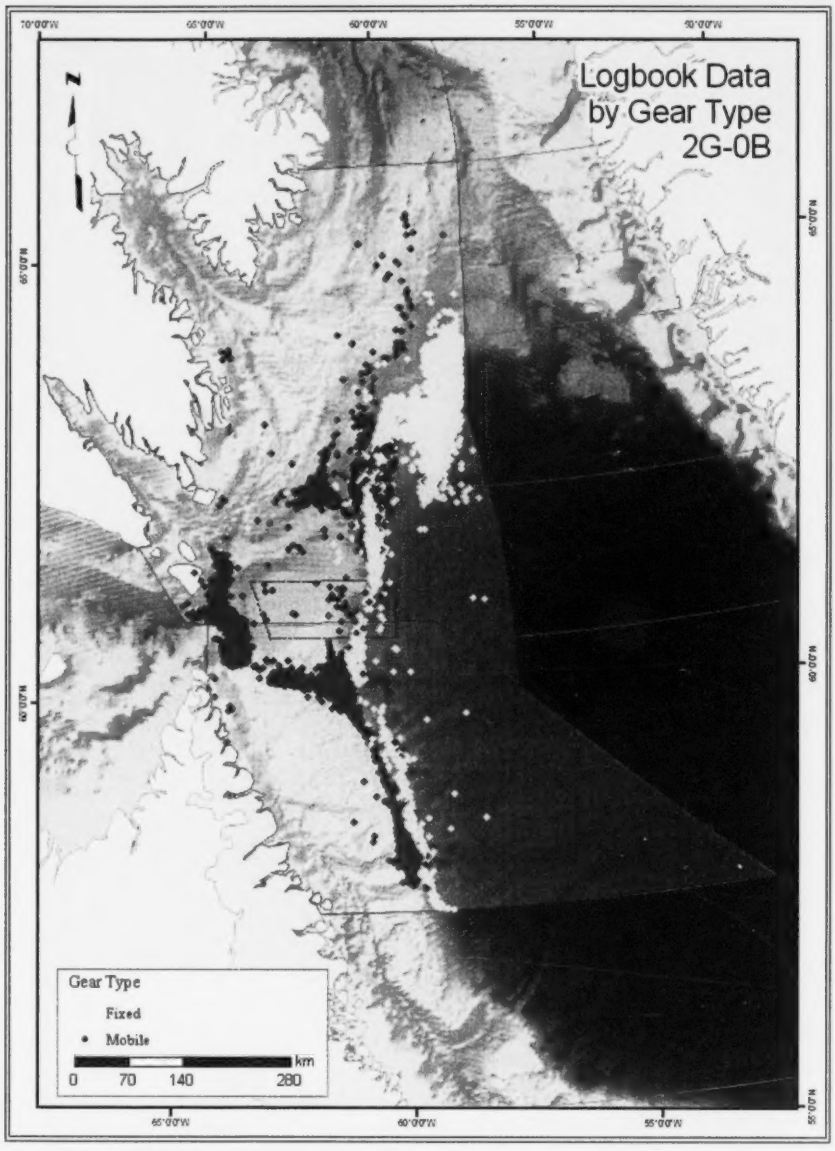

Figure 20. Logbook data for all fisheries by gear class (2G-0B).

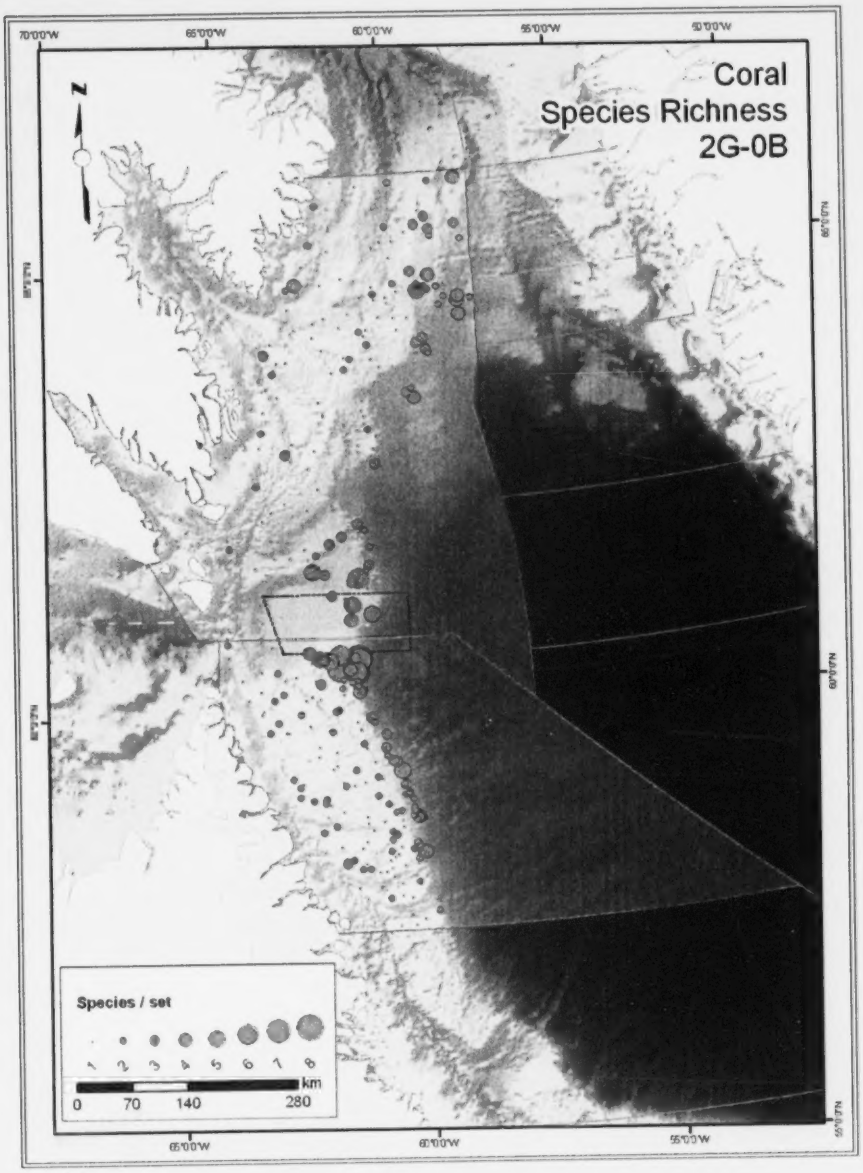

Figure 21. Coral species richness from the Northern Shrimp Survey (2G-0B).

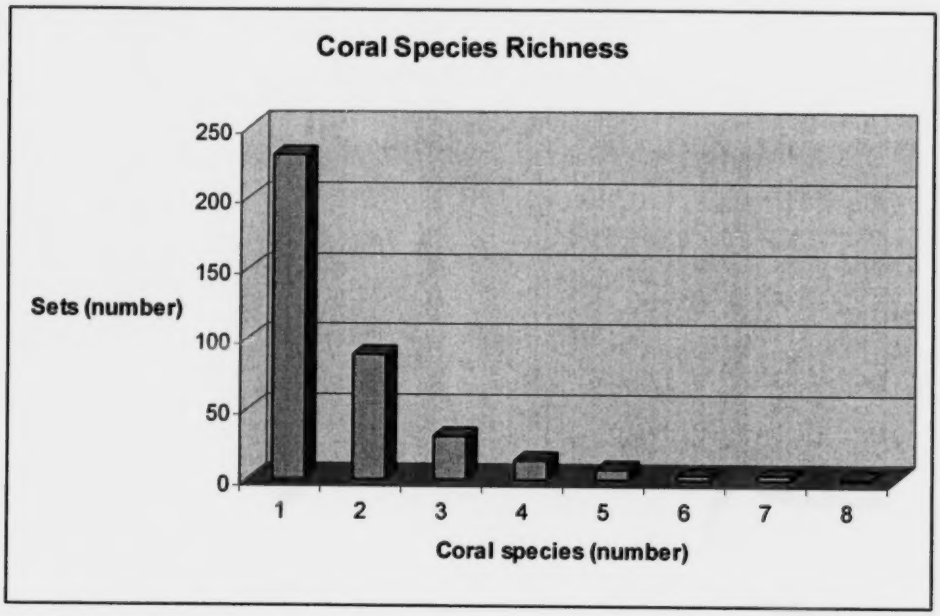

Figure 22. Species richness as the number of species per set.

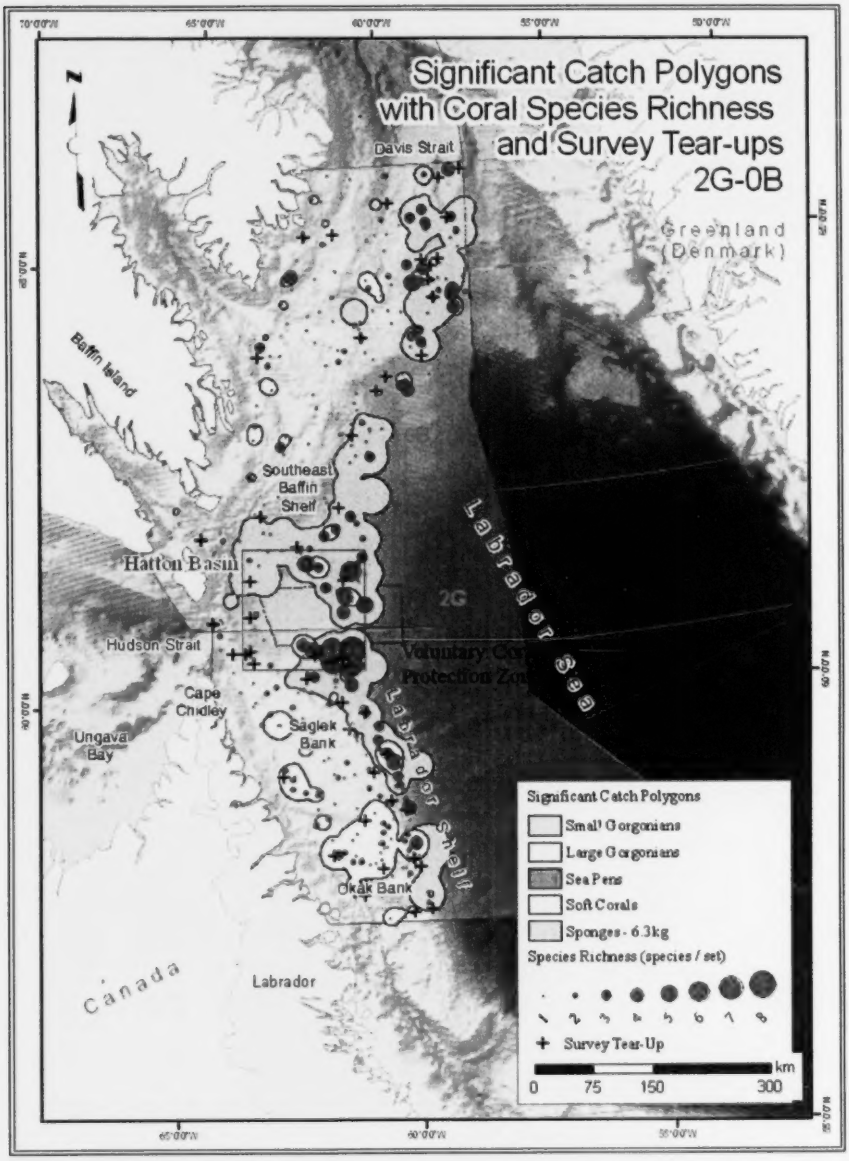

Figure 23. Density analysis (sponges using 6.3 kg threshold), coral species richness and set tear-ups.

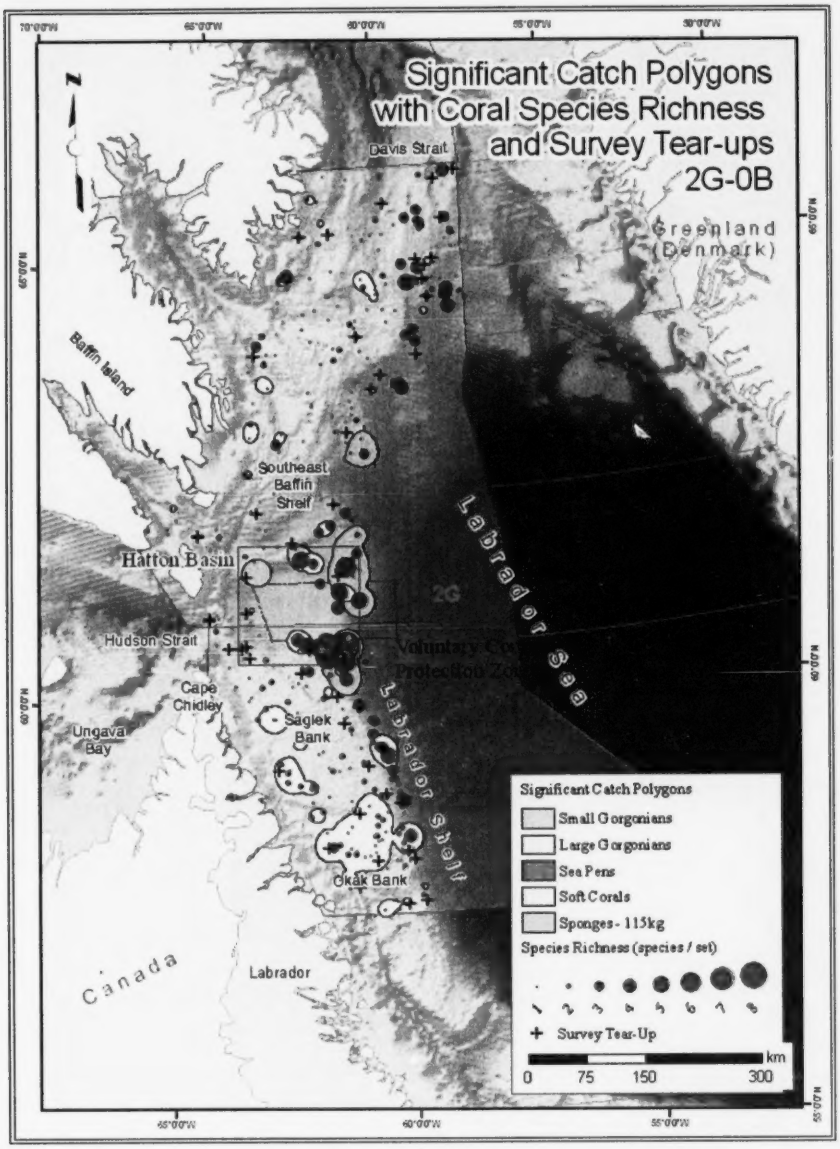

Figure 24. Density analysis (sponges using 115 kg threshold), coral species richness and set tear-ups.